ARIZONA ROAD WEATHER INFORMATION SYSTEM (RWIS) COMMUNICATIONS PLAN

Final Report 525

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DISCLAIMER

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There have been two implementations of Roadway Weather Information Systems in Arizona, known as RWIS Phase 0 and Phase 1. Each Phase has met with limited success and has on-going issues that need to be addressed before new RWIS sites are implemented.

This Research Project provides a Communications Plan for Phase 2 and addresses the basic communications problems previously encountered. These include a lack of reliable communications links in rural locations, interoperability of the RWIS sites and communications infrastructure, and publication of the RWIS data to all interested ADOT personnel.

NTCIP standards, newer commercially available communication equipment, and Internet-based publication methods will be used to successfully meet these challenges. Also, a single contractor has been chosen to upgrade existing RWIS sites and install new RWIS sites; thus ensuring a consistent implementation approach and equipment interoperability.</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	Square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	M^2	m^2	Square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	M^2	m^2	Square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	Km^2	km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	M^3	m^3	Cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	Cubic meters	1.308	cubic yards	yd^3
	NOTE: Volumes greater than 1000L shall be shown in m^3.								
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000lb)	0.907	megagrams (or "metric ton")	mg (or "t")	Mg	megagrams (or "metric ton")	1.102	short tons (2000lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION					**ILLUMINATION**		
fc	foot candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE AND PRESSURE OR STRESS					**FORCE AND PRESSURE OR STRESS**		
lbf	poundforce	4.45	newtons	N	N	newtons	0.225	poundforce	lbf
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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GLOSSARY OF COMMONLY USED TERMS

AC	Alternating Current
ADOT	Arizona Department of Transportation
AMPS	Advanced Mobile Phone Service
BER	Bit Error Rate
CDMA	Code Division Multiple Access
CDU	Control Display Unit
DPS	Department of Public Safety
ESS	Environmental Sensor Station
FCC	Federal Communications Commission
GHz	Gigahertz
HCRS	Highway Condition Reporting System
HLDC	High Level Datalink Control
IP	Internet Protocol
IT	Information Technology
ITS	Intelligent Transportation Systems
Kbps	Kilobaud Per Second
LAN	Local Area Network
LCP	Link Control Protocol
LEO	Low Earth Orbit
Mbps	Megabaud Per Second
MHz	Megahertz
MIB	Management Information Base
NCP	Network Control Protocols
NTCIP	National Transportation Communications for ITS Protocols
OSI	Open Source Initiative
PBX	Private Branch Exchange
PICS	Protocol Information Conformance Statement
POTS	Plain Old Telephone Service
PPP	Point to Point Protocol
RF	Radio Frequency
RFC	Request for Comments
RPU	Remote Processing Unit
RWIS	Road Weather Information System
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TOC	Traffic Operations Center
UDP	USC Datagram Protocol
VPN	Virtual Private Network
WAN	Wide Area Network

1.0 INTRODUCTION

The Arizona Department of Transportation (ADOT) contracted with System Innovations, Inc., to provide Road Weather Information Systems (RWIS) throughout the state. During this contract period, ADOT has installed the WeatherScene® system in 14 sites, and plans to install approximately 50 new systems at various locations statewide. This on-going process will take place over the next five years. Figure 1 shows the location of the planned RWIS sites and the 14 existing sites. The goal is to link all the RWIS sites to a central server where all ADOT personnel can gain access to the data.

The original communications architecture utilized the Arizona Department of Public Safety's microwave network. ADOT intends to phase out this analog system due to bandwidth limitations and develop a new one based on, to the extent possible, local landline or cellular phone communications. The development of this new communications architecture was performed as a research project.

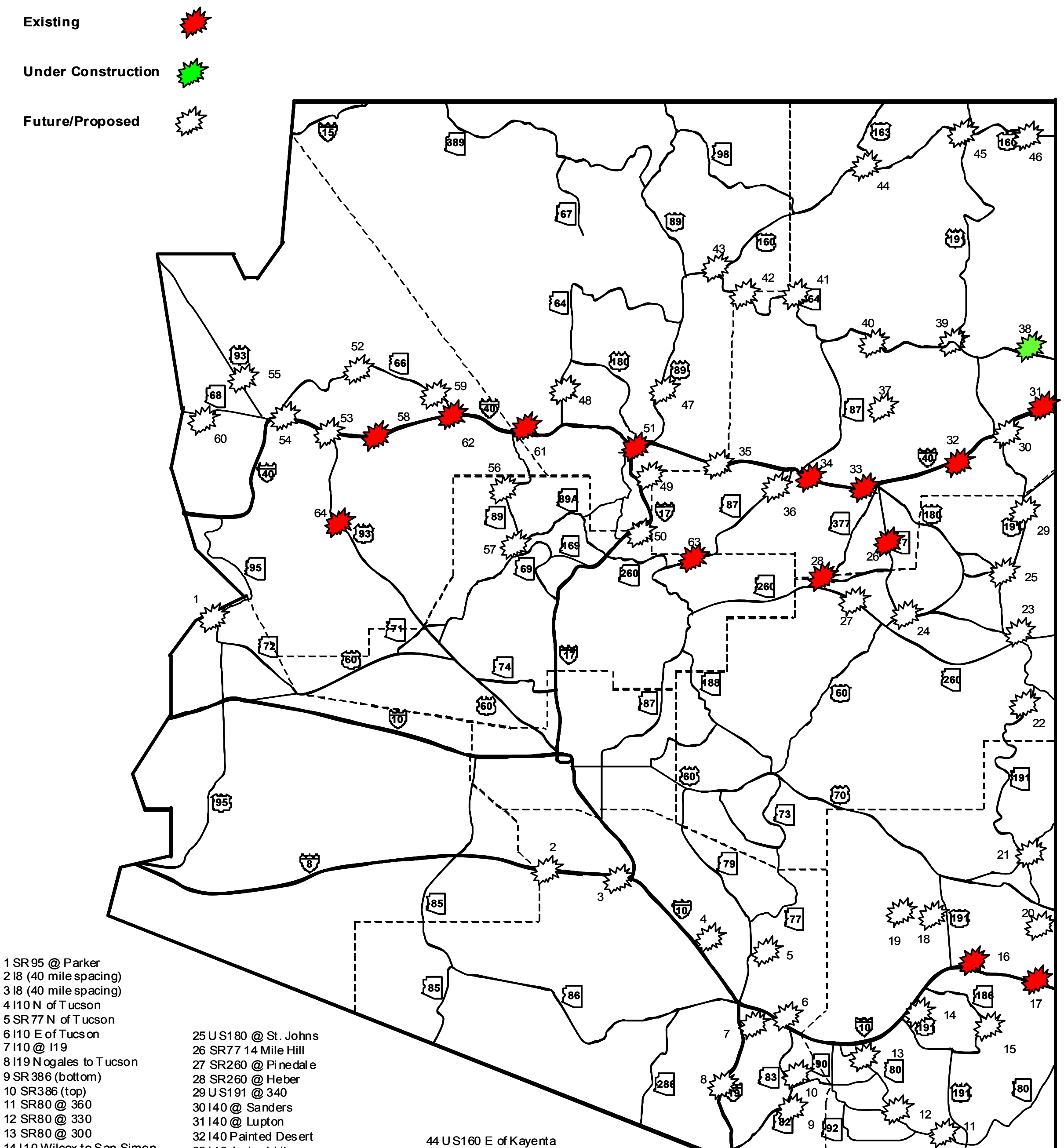
The purpose of this new communications architecture is to link all RWIS sites from the roadside to a statewide network. This document describes both a statewide architecture and the roadside to central processing unit communications connectivity. The ADOT goal is to have all the RWIS data available at the Traffic Operations Center located in Phoenix.

The communication architecture will permit integration of the RWIS equipment throughout the state and it will also include Truck Escape Ramp monitoring systems, potential Rest Area monitoring, water level flood monitors, remote area weather stations, and, in some cases, connectivity with Variable Message Signs.

This document describes the communication architecture and the various components used to complete it. The RWIS statewide communications architecture will consist of license free Radio Frequency (RF) line of sight data links, landline and cellular telephone links, both Wide Area Networks (Arizona IT Network) and Local Area Networks, the Internet, potential fiber optic networks, and possibly satellite communications links for very remote locations. This Communications Plan describes the approach used to integrate these components into a reliable data network for RWIS applications.

ROAD WEATHER INFORMATION SYSTEMS

As of February 2003



1 SR95 @ Parker
2 I8 (40 mile spacing)
3 I8 (40 mile spacing)
4 I10 N of Tucson
5 SR77 N of Tucson
6 I10 E of Tucson
7 I10 @ I19
8 I19 Nogales to Tucson
9 SR386 (bottom)
10 SR386 (top)
11 SR80 @ 360
12 SR80 @ 330
13 SR80 @ 300
14 I10 Wilcox to San Simon
15 SR181 Cher National Mnt.
16 I10 Bowie
17 I10 @ San Simon
18 US191@ 110
19 Sr266 E of Bonita
20 US70@ Duncan
21 SR78 S of Morenci
22 USFS Road
23 US60 @ Springerville
24 SR77 @ Show Low
25 US180 @ St. Johns
26 SR77 14 Mile Hill
27 SR260 @ Pinedale
28 SR260 @ Heber
29 US191 @ 340
30 I40 @ Sanders
31 I40 @ Lupton
32 I40 Painted Desert
33 I40 Jackrabbit
34 I40 Little Colorado
35 I40 @ Winona
36 SR87 S of Winslow
37 SR77 @ 408
38SR 264 @ Window Rock
39 Sr264 @ Ganado
40 SR 264 @ Keams Canyon
41 SR264 w of Orabi
42 SR264 E of Tuba City
43 US 160 @ Tuba City
44 US160 E of Kayenta
45US160 @ US191
46 US64 @ Teec Nos Pos
47 SR 89 N. Flagstaff
48 SR 64 N. Williams
49 I17 S. Flagstaff
50 I17 @ Stoneman Lake
51 I40 @ Riordan
52 SR 66 @ Peach Springs
53 I40 @ US93
54 I40 E of Kingman
55 US93 N of Kingman
56 SR 89 S Ash Fork
57 SR89 N Prescott
58 I40 Fort Rock
59 SR66 @ MP117
60 SR68@ MP12
61 I40 Ashfork Hill
62 I40 Crookton
63 SR87 @ Clint Wells
64 US93 Kaiser Bridge

Figure 1. ADOT RWIS Plan

2.0 COMMUNICATIONS REQUIREMENTS

The top level requirements for the Statewide RWIS communications approach, or design strategy, are specified by ADOT as follows:

- Remote Site Connectivity. The RWIS communications approach must provide the ability to connect any remote site along a roadway to a computer/server for further data distribution.

- District Control and Monitoring. The RWIS communications approach will allow ADOT Districts to control the RWIS sites and monitor the information.

- Centralized Data. The communications approach will allow statewide RWIS integration in Phoenix. This integration will allow ADOT's Traffic Operations Center (TOC) in Phoenix to receive RWIS information from the Districts, store it for future use, and display it on a computer/server.

- Reliable Operation. The communications approach will operate reliably with little down time or loss of data. The communications approach shall provide 95 percent availability with a Bit Error Rate less than one in 10^6 bits.

- Cost Efficient. The communications approach will provide a cost efficient solution. This solution will have minimizing long distance toll costs and cellular telephone costs as a key goal.

- Data Throughput. The communications approach will provide a nominal data rate solution of 9.6 – 14.4 Kbps for transferring data with landline and cellular telephone links.

- Unlicensed RF (IF REQUIRED). The communications approach will use unlicensed RF communications so that ADOT does not need to obtain FCC approval of the links.

- Web Based Operations. The communications approach will include web based operations which permit ADOT and the public to view RWIS data on a web page using the Internet as the communication medium. This change will immediately allow all ADOT personnel to view RWIS data on their existing desktop computers.

- NTCIP Compliance. The communications approach will comply with the National Transportation Communications for ITS Protocols (NTCIP). These NTCIP standards will be used in designing the communications architecture and in implementing the RWIS applications.

- Scalable Approach. The communications approach will enable ADOT to start with a small number of sites while still allowing a full build-out of all planned sites.

3.0 DEVICES AND PROTOCOLS

This chapter describes the communications devices and protocols supported by the WeatherScene®, OmniWatch®, and HydroWatch® equipment.

3.1 Communications Devices

Communications devices provide the primary interface with the deployed equipment. These devices are varied to promote operability in a wide range of system architectures and deployment scenarios. Devices are provided for communicating across the room or across the state.

3.1.1 Telephone Modems. For communications architectures where telephone service is available, a variety of options are available. In installations where POTS (plain old telephone system) lines are convenient, an industrial modem, such as the one shown in Figure 2, can be connected directly to the roadside equipment. These modems provide communication data rates of up to 33.6 Kbps when communicating with a comparable modem. For typical rural telephone connections, these modems will negotiate a connection speed between 12 Kbps and 19.2 Kbps. If a digital PBX is supported, as would be available from a dial-up Internet service provider, data rates up to 56 Kbps may be achieved. Extensive data compression algorithms in the RWIS equipment make it possible to retrieve data and video images in less than 2 minutes for a typical rural telephone connection.

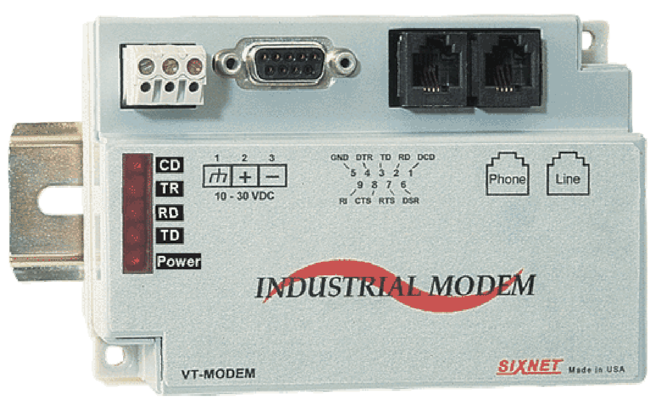


Figure 2. Industrial Telephone Modem

3.1.2 Cellular Modems. In installations where POTS land phone lines are unavailable, but cellular telephone coverage is available, a cellular data modem, such as the one shown in Figure 3, can be connected directly to the roadside equipment (as to a POTS modem). These modems are available for most major cellular systems, including AMPS (Advanced Mobile Phone Service) analog cellular, and TDMA (Time Division Multiple Access) and CDMA (Code Division) digital cellular. AMPS analog cellular modems provide communication data rates of up to 9.6 kbps, but typically negotiate to 4.8 kbps. Digital cellular modems provide data rates of up to 19.2 kbps. While slightly slower than a landline telephone connection, these communication rates are remarkably similar to data rates available over typical rural telephone connections. This makes them a useful and comparable choice for remote RWIS installations.

Due to their large rural cellular coverage, Verizon Wireless has been selected to provide cellular service for sites requiring this communications option. Verizon Wireless offers packaged plans which include a fixed number of cellular airtime minutes and long distance time in the same rate. These plans allow ADOT to manage the amount of calling time used, and manage the budget for charges. Extensive data compression algorithms in the RWIS equipment make it possible to retrieve data and video images in less than three minutes for a typical cellular call.

Figure 3. Cellular Modem

3.1.3 <u>Line-of-Sight RF Communications</u>. Wireless communications are, generally, used to extend the range of the telephone communications links to roadside equipment. Wireless modems have three advantages over traditional telephone or cellular communications links. First, with a line-of-site range approaching 20 miles, they can connect remote locations without the need for costly trenching. Second, these devices typically operate in an unlicensed frequency band and are not subject to airtime changes or licensing fees. Finally, they offer very high data rates which allow quick access to large amounts of data stored at the roadside.

These wireless modems, as shown in Figure 4, also allow other interesting communications topologies, such as point-to-multipoint and relay architectures. These modems operate in the Federal Communications Commission's industrial, scientific, and medical bands (900 MHz, 2.4 GHz, and 5.8 GHz), providing interference-resistance and license- and approval-free use to consumers. Wireless modem data rates can be up to 10s of megabits per second, although more practical, longer-range modems reach rates of 115.2 Kbps (matching the industry standard RS-232 data interface rate of the roadside equipment).

Figure 4. Wireless Modem

3.1.4 Optical Communications. Optical communications are used only in applications where the optical fiber infrastructure exists, or where driven by requirements other than roadside equipment. In cases where fiber optic communications are available, the communications architecture can be adapted to utilize it with multidrop RS-232 to fiber modems, as shown in Figure 5. These fiber modems would support linear or ring topologies, with each modem representing an addressable node on the fiber. Data rates supported by the modems are, typically, up to 115.2 kbps per node.

Figure 5. Optical Modem

3.1.5 Satellite Communications. Satellite communications, which are ideal for remote applications, are available for a number of the products covered in this communications plan. The OrbComm System allows remote devices to send data, using subscriber communicators, to users as standard electronic mail. The subscriber communicator has an RS-232 interface for the remote device, as well as a wireless communications module for communications with OrbComm's network of Low-Earth Orbit (LEO) satellites. The satellites communicate with subscriber communicators and regional Gateway Earth Stations, allowing the exchange of data between the two. In the continental United States, OrbComm delivers 90% of all messages in 6 minutes or less, and 98% of all messages in 15 minutes or less.

Figure 6. Satellite Modem

3.2 Communications Protocols

The following sections describe the communications protocols used by the systems covered in this communications architecture.

3.2.1 <u>Point-to-Point Protocol (PPP)</u>. The Point-to-Point Protocol is designed for simple links, which transport packets between two peers. These links provide simultaneous bidirectional (i.e., full-duplex) operation and are assumed to deliver packets in the order that they are sent. WeatherScene® and OmniWatch® support the full PPP standard (Request for Comments [RFC] 1661), including the features described in the following sections. WeatherScene® and OmniWatch® use PPP to establish and maintain connections with peers or hosts that require information.

- *Encapsulation*. The PPP encapsulation uses High Level Datalink Control (HLDC)-like framing and provides for multiplexing of different network-layer protocols simultaneously over the same link. To support high-speed implementations, the default encapsulation uses only simple fields, only one of which needs to be examined for demultiplexing. The default header and information fields fall on 32-bit boundaries, and the trailer may be padded to an arbitrary boundary.

- *Link Control Protocol*. To improve portability and versatility, PPP provides a Link Control Protocol (LCP). The LCP negotiates various options, such as encapsulation format, packet size limits, loop-back detection and other common misconfiguration errors, and link termination. Other optional facilities provided are authentication of the identity of its peer on the link and determination of link failure.

- *Network Control Protocols*. PPP supports families of Network Control Protocols (NCPs), which manage the specific needs required by their respective network-layer protocols. These NCPs primarily assist in the assignment and management of IP addresses.

- *Configuration*. PPP provides for self-configuration, which is implemented through an extensible option negotiation mechanism, wherein each end of the link describes to the other its capabilities and requirements.

3.2.2 <u>Internet Protocol</u>. The Internet Protocol (IP) is designed for use in interconnected systems of packet-switched computer communication networks. The Internet protocol provides for transmitting blocks of data called datagrams from sources to destinations, where sources and destinations are hosts identified by fixed length addresses. IP also provides for fragmentation and reassembly of long datagrams, if necessary, for transmission through "small packet" networks. IP implements two basic functions: addressing and fragmentation. WeatherScene® and OmniWatch® use IP, as specified in RFC 791, for these services.

3.2.3 <u>Transmission Control Protocol (TCP)</u>. The Transmission Control Protocol (TCP) provides a reliable, connection-oriented transport protocol for transaction-oriented applications. TCP is used by most network applications on the Internet today, including email and web browsers, as they require a reliable, error-correcting transport mechanism to ensure that data are not lost or corrupted. WeatherScene® uses TCP, as described in RFC 793, for transport services supporting data distribution between servers, databases, and users.

3.2.4 <u>User Datagram Protocol (UDP)</u>. The User Datagram Protocol (UDP) provides a low-overhead transport service for application protocols that do not need (or cannot use) the connection-oriented services of transport control protocol (TCP). WeatherScene® uses UDP, as described in RFC 768, for transport services supporting simple network management protocol (SNMP). In addition, WeatherScene® and OmniWatch® use UDP as the transport mechanism for digitized and compressed imagery, from roadside system to user.

3.2.5 <u>Simple Network Management Protocol (SNMP)</u>. The Simple Network Management Protocol (SNMP) is used to communicate management information between the network management stations and the agents in network elements. Specifically, SNMP allows access by an SNMP manager to data (i.e., objects) in the SNMP agent. These objects are published and maintained by the agent to supply the manager with state and control data. WeatherScene® and

OmniWatch® use SNMP to allow traffic management centers (and other users) to access data and exhibit control over roadside equipment in a consistent and standard method.

3.2.6 Other Protocols. Assorted other protocols may be used by the equipment covered in this communications plan. Examples include, fiber distributed data interface (FDDI), synchronous optical network (SONET), asynchronous transfer mode (ATM), Internetwork Packet Exchange (IPX), or IEEE 802.11 wireless ethernet. The equipment covered in this plan can use many of these protocols indirectly. For system installations where it is advantageous to use existing networks and protocols, potential interfaces to the existing networks will be evaluated on a case-by-case basis.

3.3 Communications Networks

The following sections describe the potential utility of various communications networks for the distribution of data between users.

3.3.1 Arizona Department of Transportation (ADOT) Network**.** The ADOT network consists of Local Area Networks (LANs) and Wide Area Networks (WANs) to branch offices and remote users over private WAN links. Various network architectures are in use, including token ring and 10/100baseT Ethernet, among others. The ADOT network may also include virtual private network (VPN) connections between districts to augment the bandwidth of the private WANs between districts or other users. Dial-up connections into the network are, generally, discouraged, to prevent unauthorized access to the ADOT intranet. Bandwidths available to users across various segments of the LAN/WAN vary, based on location and time of day. Most District offices are connected to the WAN via a T1 (1.544 Mbps) connection. Smaller Maintenance offices typically connect via a Fractional T1 or Frame Relay connection (56 Kbps) or equivalent. These connection types will allow all ADOT personnel to view web based data and retrieve RWIS information via the ADOT WAN.

3.3.2 Internet. Internet service providers, including providers of data bandwidth, are available in most areas of Arizona. Dial-up services, providing bandwidths of up to 56 Kbps are most widely available. Access to these services is via standard V.90 telephone modems. Data bandwidth providers, offering DSL, T1, T3, and higher bandwidth services, are available in most metropolitan areas. Access to these services is via dedicated DSL modem or router, as appropriate.

3.4 WeatherScene® NTCIP Compliance

NTCIP compliance of the WeatherScene® system is summarized by the diagram in Figure 7, excerpted from Reference 1. Table 1 below gives outline descriptions of WeatherScene® NTCIP compliance, detailed further in the text.

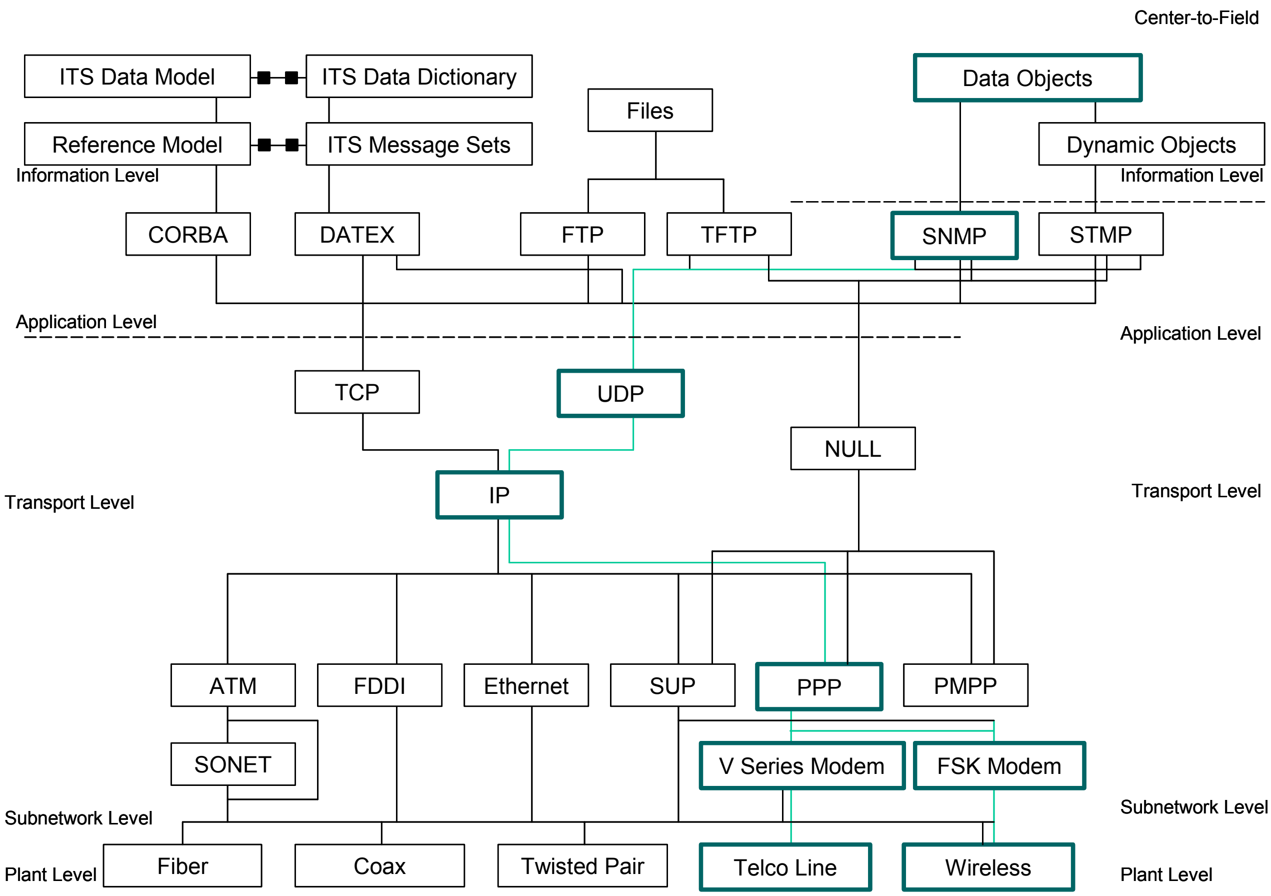


Figure 7. WeatherScene® NTCIP Compliance Summary Diagram

Table 1. NTCIP Compliance Description Index

Level	Description	Section
Plant	WeatherScene® uses standard telephone lines or wireless links as its plant or physical layer.	3.4.1
Subnetwork	WeatherScene® uses Point-to-Point Protocol (PPP) over V-series telephone modems or wireless data modems as its subnetwork level	3.4.2
Transport	WeatherScene® uses User Datagram Protocol (UDP) over Internet Protocol (IP) as its transport level.	3.4.3
Application	WeatherScene® uses Simple Network Management Protocol (SNMP) as its application level.	3.4.4
Information	WeatherScene® uses data objects from the following Management Information Bases • Environmental Sensor Station Objects • WeatherScene®-specific Objects	3.4.5

3.4.1 Plant Profile. The plant level interface to the WeatherScene® RPU is a standard telephone line, a cellular phone connection, or an RF wireless modem link as appropriate for the given WeatherScene® installation. There are no special NTCIP requirements specified for the plant level.

3.4.2 Subnetwork Profile. The subnetwork profile specifies a set of protocols and standards applicable to the data link and physical layers of the Open Source Initiative (OSI) reference model. The subnetwork profile for WeatherScene® is the point-to-point protocol (PPP) over RS232. NTCIP 2103 (Reference 2), documents the detailed requirements for this subnetwork protocol. WeatherScene® is fully compliant with NTCIP 2103, as documented in the completed profile requirements list (PRL) and protocol implementation conformance statement (PICS) contained in the WeatherScene® Remote Processor Unit NTCIP Compliance Document (Reference 8). Upon balloting and approval of this standard, the WeatherScene® RPU interface will be reviewed to determine its compliance with the approved standard.

3.4.3 Transport Profile. The transport level profile specifies a set of protocols and standards applicable to the transport and network layers of the OSI reference model. The transport profile provides message transport and delivery services between transportation devices and management stations. The transport profile for WeatherScene® is the Internet transport profile, specifically user datagram protocol (UDP) over Internet protocol (IP). NTCIP 2202 (Reference 3) documents the detailed requirements for this transport protocol. The WeatherScene® RPU is fully compliant with NTCIP 2202, as documented in the completed PRL and PICS contained in WeatherScene® RPU (Reference 8), as required by NTCIP 2202.

3.4.4 Application Profile. The application level profile specifies a set of protocols and standards applicable to the application, presentation, and session layers of the OSI reference model. The application profile should provide message authentication, information management, and data representation services for devices and management stations. The application profile for WeatherScene® is the simple transportation management framework (STMF) application profile, conformance level 1. NTCIP 2301 (Reference 4) documents the detailed requirements for this application profile. WeatherScene® is fully compliant with NTCIP 2301, as documented in the completed PRL and PICS contained in WeatherScene® RPU (Reference 8), as required by NTCIP 2301.

3.4.5 Information Profile. The information profile specifies logically grouped sets of data that devices and management stations can exchange. These object definitions, documented in standard management information bases (MIBs), provide a common basis for peers to communicate transportation-related information. WeatherScene® is an environmental sensor station and, thus, complies with the following NTCIP object definitions:

- NTCIP object definitions for ESS, documented in NTCIP 1204 (Reference 5)
- WeatherScene®-specific object definitions

The following sections detail the information profile compliance of WeatherScene® as well as document WeatherScene®-specific objects. WeatherScene® is compliant with all mandatory requirements of the ESS standard.

3.4.5.1 Environmental Sensor Station Objects. NTCIP 1204 specifies conformance groups to be used as minimum requirements for specifying varying degrees of compliance with the standard.

The following Table 2, the *ESS (Environmental Sensor Station) MIB (Management Information Base) Conformance Group Summary*, details the WeatherScene® RPU's conformance with the groups documented in NTCIP 1204. Each supported group is detailed in the sections of the WeatherScene® RPU compliance document (Reference 8), as indicated in the last column of Table 2.

Table 2. ESS MIB Conformance Group Summary

Conformance Group	Conformance Requirement	WeatherScene® Conformance	Details in Reference 8 Section…
Configuration	mandatory	Yes	2.5.1.1
Database Management	optional	No	N/A
Time Management	mandatory	Yes	2.5.1.2
Timebase Event Schedule	optional	No	N/A
Report	optional	No	N/A
STMF	optional	No	N/A
PMPP	optional	No	N/A
ESS Configuration	mandatory	Yes	2.5.1.3
ESS Location	mandatory	Yes	2.5.1.4
Pressure	optional	Yes	2.5.1.5
Wind Data	optional	Yes	2.5.1.6
Mobile Wind Data	optional	No	N/A
Basic Temperature Data	optional	Yes	2.5.1.7
Enhanced Temperature Data	optional	Yes	2.5.1.8
Basic Precipitation Data	optional	Yes	2.5.1.9
Standard Precipitation Data	optional	Yes	2.5.1.10
Enhanced Precipitation Data	optional	Yes	2.5.1.11
Emerging Precipitation Data	optional	No	N/A
Solar Radiation	optional	Yes	2.5.1.12
Visibility Data	optional	Yes	2.5.1.13
Standard Pavement Sensor Data	optional	Yes	2.5.1.14
Enhanced Pavement Sensor Data	optional	Yes	2.5.1.15
Standard Sub-Surface Sensor Data	optional	Yes	2.5.1.16
Enhanced Sub-Surface Sensor Data	optional	No	N/A
Emerging Mobile Platform	optional	No	N/A
Pavement Treatment	optional	No	N/A
Air Quality	optional	No	N/A
Staffed Station	optional	No	N/A

3.4.5.2 WeatherScene®-Specific Objects. As shown in Figure 8, the WeatherScene®-specific objects reside in two nodes under the System Innovations private enterprise node (10413), which was granted by the Internet Assigned Numbers Authority (IANA). The two nodes are named TSS (4) and RPU (1). These are detailed in the following section to illustrate the interoperability between management stations and WeatherScene® roadside equipment.

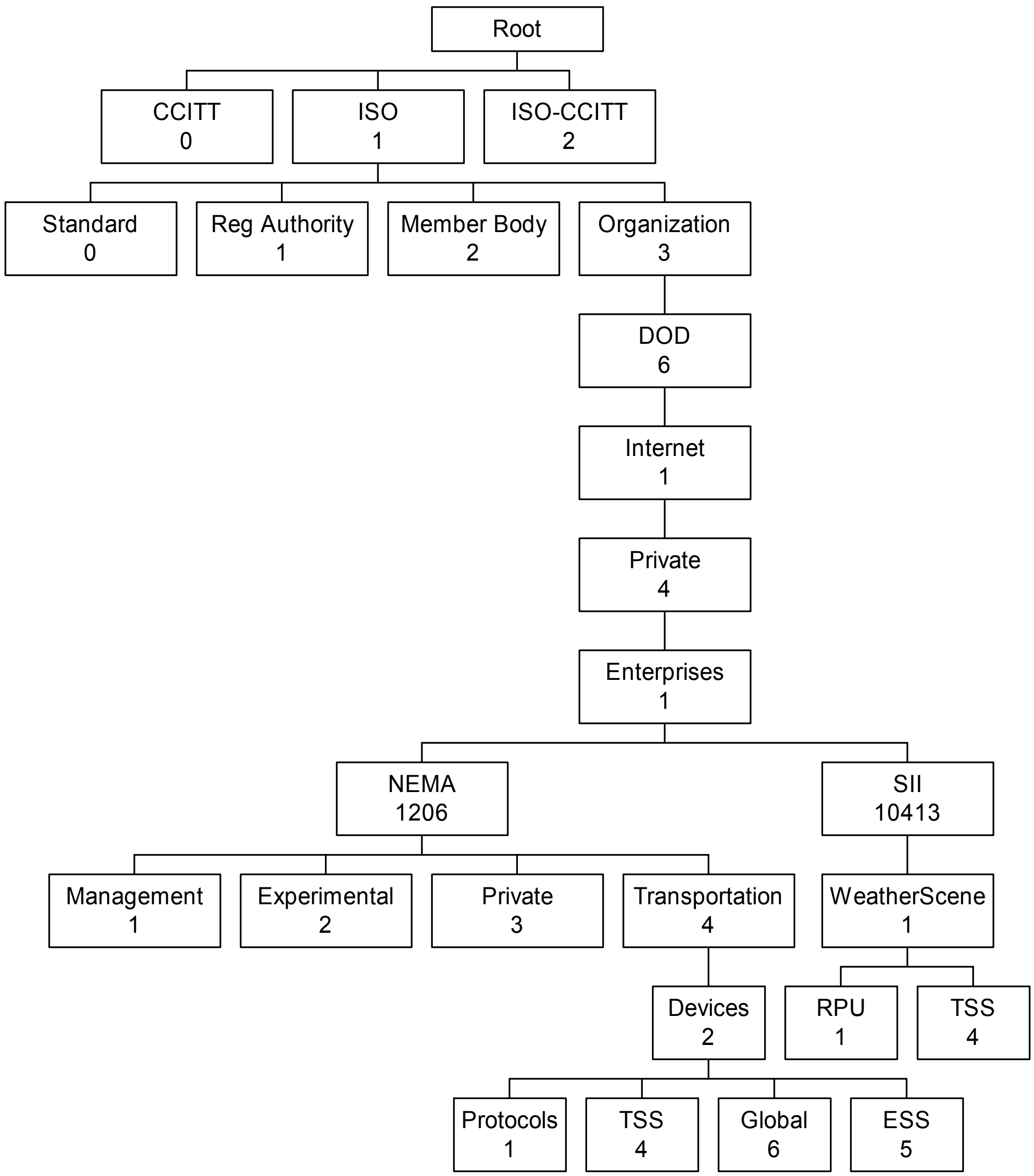


Figure 8. WeatherScene® MIB Node Location Diagram

3.4.5.2.1. WeatherScene® TSS-Like Objects. WeatherScene® RPUs include optional traffic sensor systems to provide information, such as traffic counts, lane occupancies, and vehicle speeds. The model for the object definitions in this WeatherScene®-specific node is NTCIP 1209 (Reference 7), which is currently in draft form. Upon balloting and approval of this standard, the WeatherScene® RPU object definitions will be reviewed to determine their compliance with the approved standard. Table 3 and subsequent sections provide an overview of the objects in this MIB. For more details, see the MIB data in the WeatherScene® Remote Processor Unit compliance document (Reference 8).

Table 3. WeatherScene® TSS-Like Object Summary

Group	Summary Description
Configuration	This group provides objects related to the configuration of the traffic sensor zones.
TSS Data Collection	This group provides objects related to the collection and storage of the traffic sensor data.

3.4.5.2.2. WeatherScene® Objects. WeatherScene® includes a vendor-specific MIB to provide access to the configuration, status and control information not available through the NTCIP standard MIBs. The following sections provide an overview of the objects in this MIB. For more detail, see the MIB data in Reference 8.

Table 4. WeatherScene® MIB Group Summary

Group	Summary Description
RPU Setup	This group provides objects related to the configuration of the WeatherScene® RPU.
RPU Status	This group provides objects related to the status of the WeatherScene® RPU.
RPU Video	This group provides objects related to the control and collection of video from the WeatherScene® RPU.
RPU Net Configuration	This group provides objects related to the configuration of the networking layers within the WeatherScene® RPU.
RPU Control	This group provides objects related to the control of gadgets within the WeatherScene® RPU.
RPU Alarms	This group provides objects related to the configuration of alarm processing within the WeatherScene® RPU.
RPU Schedules	This group provides objects related to the configuration of the measurement scheduler within the WeatherScene® RPU.
RPU Data Logs	This group provides objects related to the logging of sensor data within the WeatherScene® RPU.

4.0 STATEWIDE RWIS COMMUNICATIONS ARCHITECTURE

An overall system architecture using the Arizona statewide WAN as the backbone for sharing information will be implemented. Figure 9 provides an overall view of how this system will communicate. At each of the District Offices, an NTCIP compliant Control Display Unit (CDU) server will have direct contact through phone lines (or cellular) to each of the RPUs that are in that particular District. Information from each of the RPUs will be maintained at the District level. A display will be provided so that the District Office operations center will be able to receive data from each unit assigned to that CDU, display the information and control each RPU. Each of the District CDUs will be connected to the Arizona statewide wide area network (WAN).

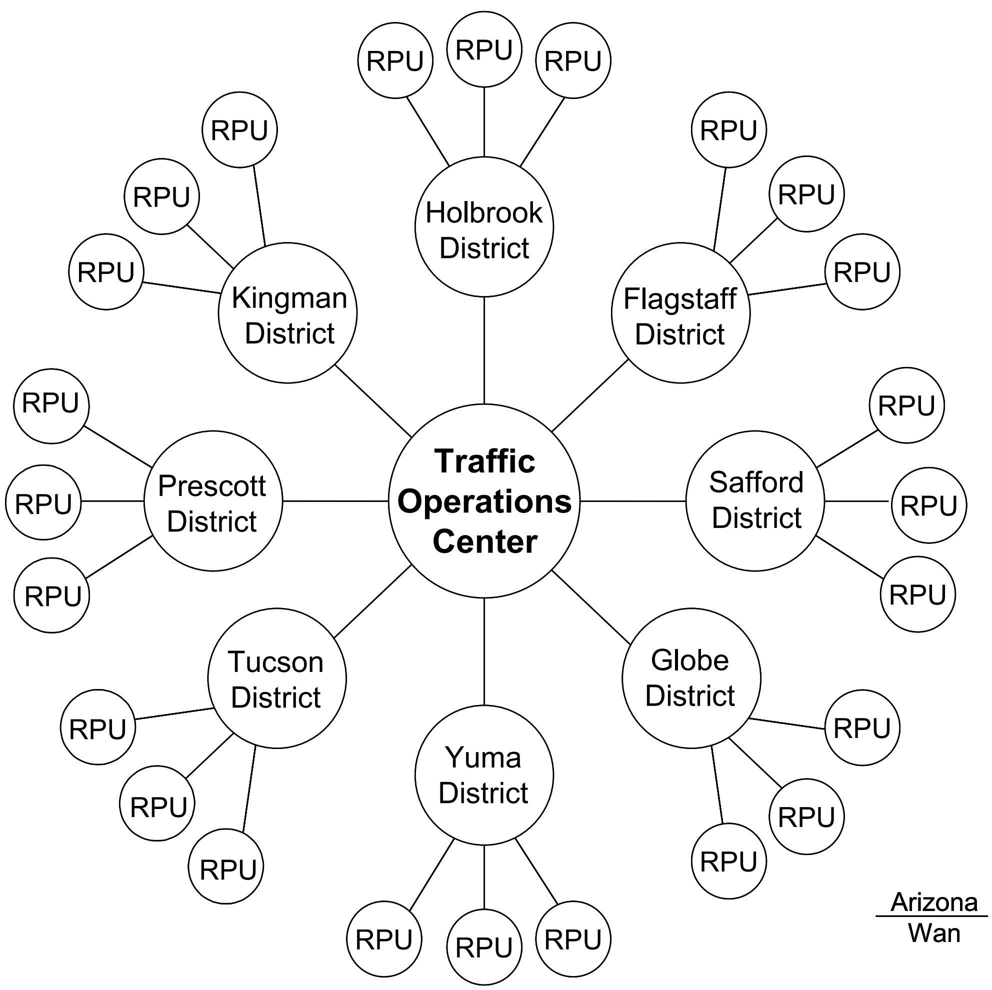


Figure 9. Statewide RWIS Communications Architecture

During the initial rollout (Year One) of RWIS sites by ADOT, a single CDU will be installed at the Flagstaff District Office. This CDU will be responsible for communicating with all 14 RWIS sites currently planned for Year One. ADOT decided to install a single CDU to simplify deployment of the initial system, maximize funding resources, and gain valuable operational experience with the system. The Flagstaff District was chosen because it has the highest concentration of sites. Although many of the RWIS sites are located in different districts, the selection of cellular communications through Verizon Wireless allows ADOT to bypass long distance charges that could otherwise be a hurdle for this approach. Moreover, the Web server capability of the CDU allows a single CDU to publish information statewide to all interested ADOT personnel using the ADOT WAN.

In this single CDU configuration, all ADOT personnel with Intranet access will be able to view RWIS information from all sites. They will be presented with a map based web page (similar to the Highway Condition Reporting System page on AZ511.com) where they can select a particular RWIS site. Current and historical information may be browsed or downloaded as required by the user. No password will be required to access the information portion of the site. In addition to this "View Only" capability, a password-accessible portion of the site will allow authorized personnel to command the CDU to poll an individual RWIS site, retrieving the latest weather data from that location. All other configuration aspects of the system (user administration, site configuration, etc.) will be performed locally on the CDU. VPN software will be installed on the CDU to allow ADOT's Information Technology (IT) personnel to perform these functions remotely if required, but normal operational procedures will be executed locally.

ADOT's goal is to deploy a CDU in every District Office. This approach has several advantages. Distributing CDUs provides a more resilient network, offering redundant infrastructure components and minimizing ADOT's vulnerability to emergencies that may occur at a single facility. This architecture minimizes dependence on and bandwidth utilization of the ADOT WAN. It also shortens the overall communications path (via wireline or cellular) to RWIS sites which will result in more reliable and lower cost communications options. This configuration also improves CDU performance by minimizing the number of sites that a single CDU must service. The practical limit for the number of sites that a single CDU can service is 20.

In addition to the communications benefits derived from distributing CDUs in every district, this configuration easily supports ADOT's goal of integrating RWIS data with the Highway Condition Reporting System (HCRS). The long-term goal is to move historical RWIS data from the District CDUs to a central database server at the Phoenix Traffic Operations Center (TOC). With the District CDU servers reporting updated information to the TOC server, the information can be routed easily to the Highway Closures and Restrictions

System (HCRS) server for public access. This public access server will have a firewall to protect against public penetration of the ADOT network.

Each of the District CDUs will continue to have a map-based web page that will allow ADOT personnel to access the Intranet web page and view traffic, road and weather data, and imagery from any of the district RWIS systems. The web page user will only be able to view data and imagery, and will not have access to control the sites. Using a password scheme, “super users” will, via the web page, have control privileges to connect with RPUs and request a polling update.

4.1 Remote Processing Unit (RPU) Communications

The RPU is the remote site unit that accumulates all of the data from the sensors and formats it in NTCIP compliant files for transfer to the user. The RPU has a variety of communications paths it can use to send the data, as shown in Figure 10. These communications paths will be primarily a landline telephone link to a Computer/Server or an RF link to a telephone line using an RF Telephone Relay Unit. This latter path provides a wireless connection from the RPU at the roadside to a nearby telephone line without a requirement to run the telephone line to the site. While these two communications paths will make up the majority of the RWIS communications links, the Communications Architecture will accommodate other links. The following Communications Infrastructure Paths can be used:

- Landline Telephone to a Computer/Server
- Cellular Telephone to a Computer/Server
- Telephone to Internet
- Fiber Optic Cable Communications
- RF Link to a Computer/Server
- Local or Wide Area Network (LAN/WAN) to a Computer/Server

The RPU can use one or more RF Communications Relays to extend the range of the RF link. This RF link from the RPU can terminate at a Computer/Server using an RF Communications Interface Unit. This link can also terminate at an RF Telephone Relay Unit which translates the RF datalink into a telephone modem data link. The RPU can connect via an RS-232 serial port to interface units for a LAN/WAN or to interface units for a fiber optic communications cable.

As stated earlier, the preferred communications path will be a landline telephone link. In this configuration, a normal telephone line will be connected to the RPU with a specific telephone number. The RPU will receive data requests by the District CDU server modem calling the phone number of the RPU and establishing a data connection between the two modems. Once the connection is made, the CDU server will request, via NCTIP-compliant commands, the selected weather, traffic, road conditions and video data. This data will be stored on the District CDU server.

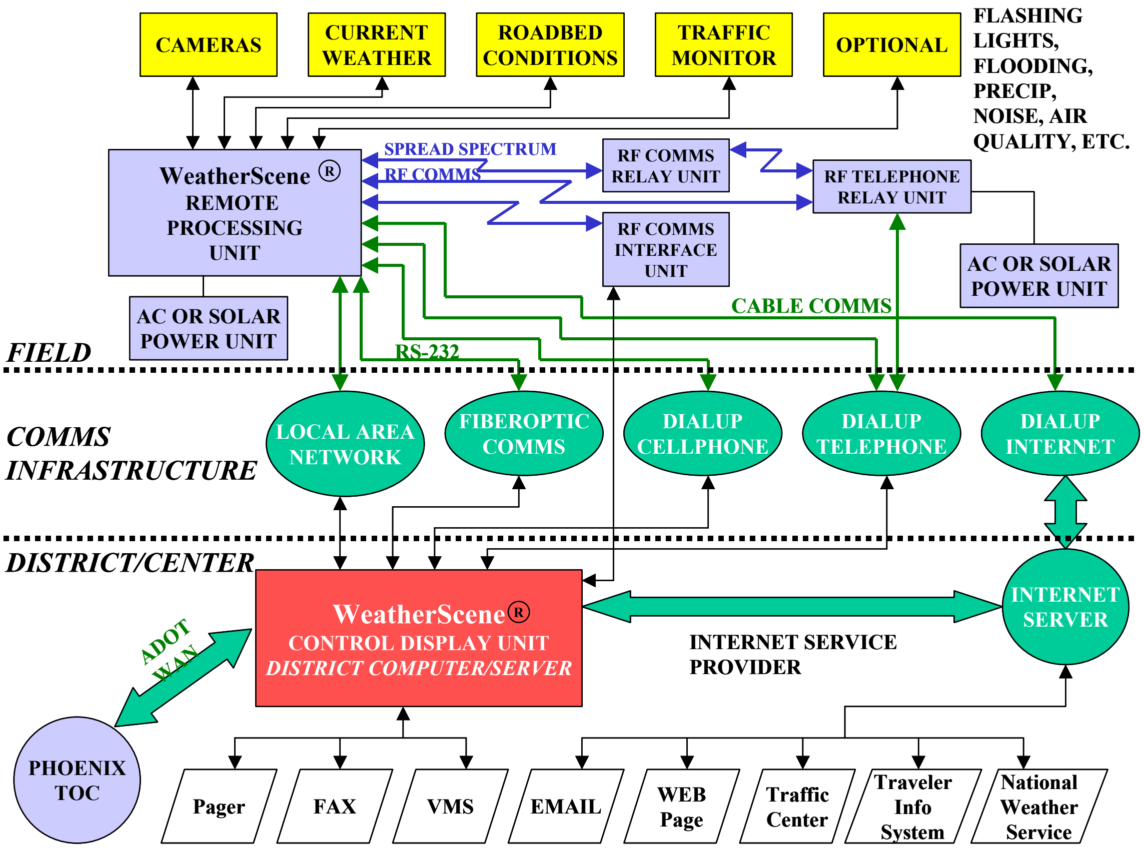


Figure 10. RPU Communication Paths

Where landline telephone links are not available, cellular communications links will be the second preferred approach. As reviewed earlier, cellular communication links offer similar performance to typical rural landline links, and cellular coverage is generally available along Interstate and State roads.

In those areas where phone service is either physically unavailable at the RWIS site or it is not economically feasible to bring phone service to the RWIS site, an RF radio system can be installed that will send the data signal to where phone service is available. This technical solution does have some operational and maintenance issues associated with it. These include: when installing or troubleshooting, technicians are required at each end and relay in the link; sophisticated equipment is required; and specialized training is needed for the technicians. These issues have prevented success in similar types of deployments in the past, and for these reasons will be the option of last resort for the ADOT architecture.

Where deployed, the RF system will use 2.4GHz data modems that can send data at 115Kbps to a phone modem. The only requirement is that the two ends of the system must be within RF line of sight. Normally under good conditions, this link can send data between 5-10 miles with good line of sight. For those areas where either the link needs to cover more distance or a clear line of sight cannot be attained in a single link, a repeater site can be installed between the two systems. This reduces that data link to 56Kbps, but as long as the repeaters are in line of sight, the link can cover 20-40 miles without problems. The RF to phone conversion site can be either mounted on a telephone pole (solar powered) or the signal can be routed to, for example, an ADOT maintenance facility where the electronics can be installed in the facility and powered with available utility power. The RF-to-phone conversion is accomplished by installing an RF Telephone Relay Unit.

These RF Spread Spectrum 2.4GHz modems operate under FCC Part 15, which allows license-free operation when operating under 500mw of power. The throughput for the modems is 115Kbps when operating in the point to point mode and 56Kbps when operating in the repeater mode. Up to 4 repeaters can be inserted in the communications path without problems. A program supplied by the manufacturer, Freewave, will be used to verify the link quality of each leg of the communications path. This program analyzes the following parameters:

- Average Signal Level: This number indicates the level of received signal at the measurement site. The number is an average of the received signal levels measured at each frequency in the modem's frequency hop table. For a reliable link, the average signal level should be at least 15 units (on a 0 to 100 unit scale developed by the manufacturer) higher than the average noise level reading.

- Average Noise Level: This level indicates the level of background noise and interference at the measurement site. The number is an average of the noise levels measured at each frequency in the modems' frequency hop table. Average noise levels typically fall in the range of 15 to 30 units. Average noise levels significantly higher than this are an indication of a high level of interference that may degrade the performance of the link.

- Overall Receive Rate (Percent): This measures the percentage of data packets that were successfully transmitted from the master to the slave on the first attempt (i.e., without requiring retransmission). A number of 75 or higher indicates a robust link that will provide very good performance. A number of 25 or lower indicates a weak or marginal link that will reduce the data throughput.

- Range: This is the calculated line of sight distance between the two modems.

At each site where RF is to be used as part of the communications architecture, an RF survey will be conducted and a test will be run to determine the viability of the link against the manufacturers recommended values. In addition, a 24 hour Bit Error Rate Test (BERT) will be conducted to verify the error rate is below 10^{-6}. If above 10^{-6}, additional steps will be required to get the BERT below the 10^{-6} error rate. A test plan will be developed by ADOT prior to the actual test describing the RF test to be conducted.

Due to the topography, several of the existing systems are located in areas where there is no phone service within an economical distance. Currently, these sites are using the Motorola 216 VHF Data Radios and are connecting to Arizona Department of Public Safety microwave system repeaters strategically positioned on mountaintops. In these areas, use of a cellular modem is recommended since most of the sites are located along interstate highways that have good cellular coverage. For example, the existing RWIS site at Fort Rock has good cellular coverage from Verizon Cellular, but is 20 miles from local phone service. The major impact in using cellular modems is the reduced data throughput that limits the data link to 4800 to 9600bps depending on the quality of the cellular link. This will lengthen the amount of connection time for the RPU to send its data (from 2 minutes to 3 minutes).

4.2 ADOT District Office Communications

The ADOT District Office communications will consist of Public Switched Telephone Network (PSTN) lines that are used to connect to the RPUs, Fax units, pagers, and Variable Message Signs; and an Arizona Wide Area Network Connection to other District Offices and to the Phoenix Traffic Operations Center. The District computer/server is a WeatherScene® Control Display Unit (CDU). This CDU has an applications software program that allows the operator to display the RPU data and control all of the RPUs in the District. The CDU has server software that periodically polls each RPU using NTCIP standard communications and downloads the RPU RWIS data and real time images from the roadside RWIS unit. This data is stored on files in the CDU. The CDU applications software includes web server software that allows an external user to access this data using the Intranet (Arizona WAN).

The public access to the RWIS information will be via a server at Phoenix with firewall protection. This prevents the public from gaining access to the District computer/server. The CDU computer/server will have an Ethernet Port to connect into the Arizona WAN. The Phoenix Traffic Operations Center will be able to access the District WeatherScene® computer/server using TCP/IP protocols over this Ethernet link. This link will provide access to both the data and the command and control of the RPUs at the RWIS sites.

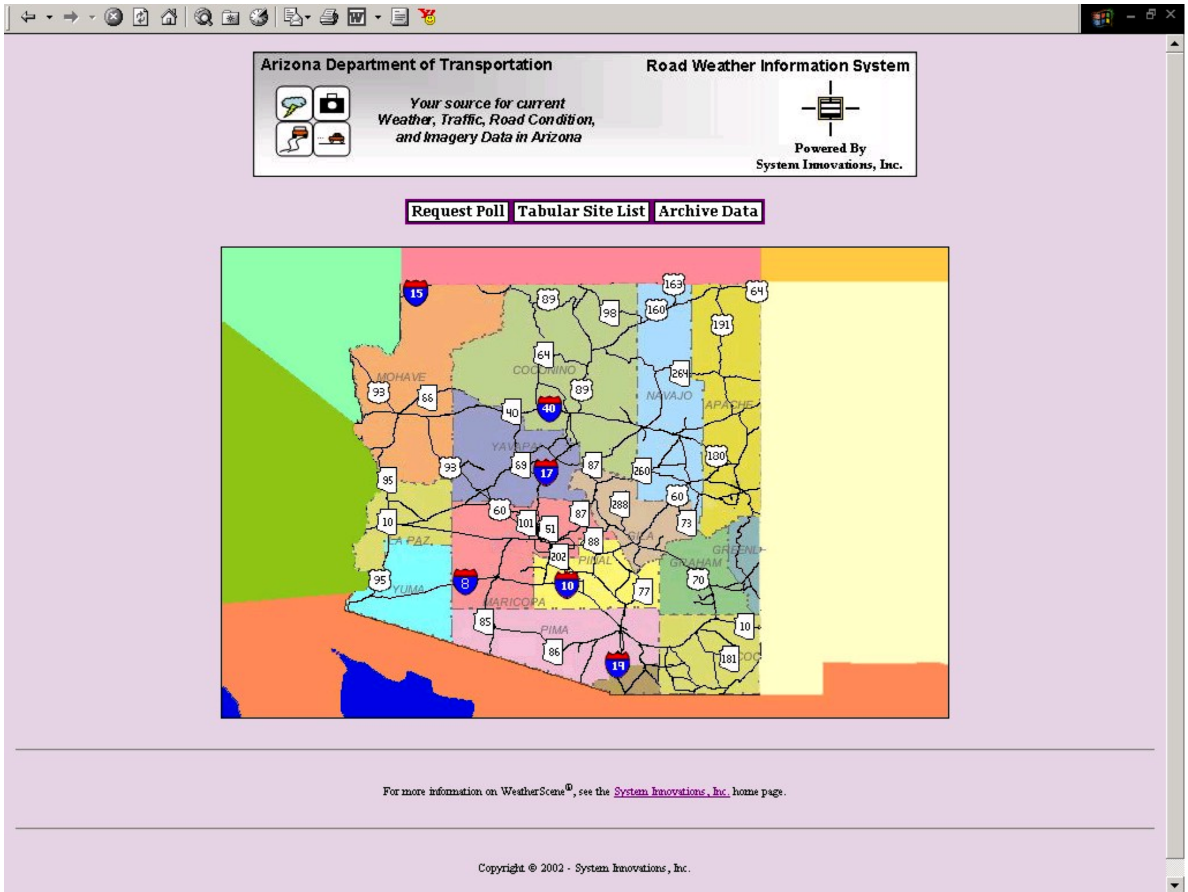


Figure 11. ADOT Intranet Web Page for RWIS Sites

4.3 Phoenix Traffic Operations Center Communications

The Phoenix Traffic Operations Center (TOC) will display RWIS information from all of the sites. The principle communication path for this information will be the Arizona IT Network. The Arizona IT Network connects state offices together. This network is available at the TOC and at the ADOT District Offices. Using an Ethernet protocol, computer servers at the TOC will be able to retrieve data stored on CDUs located in the District Offices. Once collected in a central database, ADOT can integrate enterprise-wide applications such as HCRS with the statewide weather information.

5.0 RWIS COMMUNICATIONS NETWORK DEVELOPMENT

The RWIS Communications Network will be designed and implemented over a five-year period under the Statewide RWIS contract awarded in 1999. This Plan, as described below, is the basis for the design and installation of the communications systems.

5.1 Site Surveys

ADOT has contracted with System Innovations to survey potential RWIS equipment sites to determine the availability of communication infrastructure to support each site. The infrastructure survey will include the availability of phone lines, cellular coverage, and the presence of Internet Service Providers. System Innovations will also survey the District Offices to determine the presence and type of connection for Internet service. The District Office surveys will determine the presence of an Arizona IT Network and the technical interface requirements. The surveys will also determine the availability of cellular service at the District Office and the availability of telephone lines. These RWIS site and District Office surveys will be used to design the communications components to be installed in each District implementation. The design will be one of the communications variations described in this plan.

5.2 Hardware Design

The RWIS sites will have various combinations of weather sensors, traffic monitors, roadbed sensors, and video cameras. These sensors are controlled by the Remote Processing Unit (RPU), and they send their data to the RPU. The RPU administers all of the communications between the RWIS site and the District Office CDU. The RPU will be configured in most cases with a phone modem for direct telephone connection to the CDU, cellular connection, or an RF Modem for RF connection through an RF Telephone Relay Unit (sometimes with an RF Relay in between) to the CDU. The principle communications paths for an RWIS site are shown graphically in Figure 10.

ADOT requires a system design for each RWIS site which will include the communications design for that site. The RWIS contractor will develop these designs and provide them to the ADOT Engineer along with a Communication Test Plan for verifying the communications link. The Communications Test will verify reliable connections (95 percent availability) and low Bit Error Rate (BER) performance. A BER of less than one error per million bits will be maintained.

5.3 Software Design

All of the communications are controlled by software. The software is all designed to comply with the NTCIP standards architecture as shown in Figure 8. The ADOT RWIS communications use open standards such as Point to Point

Protocol (PPP), Internet Protocol (IP), Transmission Control Protocol (TDP), User Datagram Protocol (UDP), RS-232 Serial Communications Protocol, Ethernet Network Protocol, and Simple Network Management Protocol (SNMP). Contained within these open standards and the NTCIP standards is a defined means of formatting the data, storing the data, communicating the data, controlling the system, controlling the communications, displaying the data, and interfacing to the Internet.

The WeatherScene® application software in the RPU and the CDU manage the system communications. This management allows the system to communicate data and images in a manner that is transparent to the user. The system software automatically retries either phone modem or cell modem transmission (up to 6 times) when the link is not completed. The software insures that the data files sent are the same data files that are received at the other end of the link. If errors are detected in data files they are corrected by forward error correction or the files are resent. The combination of effective retry mechanisms and error correction ensures that important information will reach the CDU even in adverse conditions. The software automatically dials telephone numbers or Internet routing numbers to complete the links. The software recognizes the RF network routing and manages link conflicts when more than two users are trying to use one link channel. The software also routes E-mail messages, E-mail to Fax, and E-mail to Pager messages.

5.4 Other ITS Systems

ADOT developed this communications plan to accommodate future remote sensor systems supporting ITS infrastructure. ADOT is building two Truck Escape Ramp Alert Systems which will provide alarms and images of the ramp when a truck uses the truck escape ramp. These two sites will be connected to the Kingman District Office using a cellular phone link. Although this system is separate from the RWIS infrastructure, it uses similar NTICP networking standards, and it leverages ADOT’s use of cellular data connections in rural areas. Additional ADOT personnel will have application software on their computers to view the runoff ramp. These additional users will receive the information via a dialup telephone from the Kingman District computer to their computers.

Working in partnership with the RWIS contractor System Innovations, ADOT may elect to deploy other remote sensor systems throughout Arizona. System Innovations currently manufactures two systems of interest. The first is a water level measuring system call HydroWatch®. HydroWatch® can be deployed in remote river beds, washes, and culverts to monitor water level and flow conditions impacting roads and land transportation. This product uses a variety of communications paths including satellite communications. The Communications Plan will be revised to accommodate this system if it is used in the future.

For extremely remote areas, System Innovations manufactures a remote weather station called OmniWeather® that can provide complete weather information. OmniWeather® is available in man-portable or air-droppable versions, is rugged, lightweight, and suitable for harsh environments. This system uses the same satellite communications paths as HydroWatch® and will therefore be compatible with the Communications Plan.

System Innovations also manufactures OmniWatch®, a remote surveillance product that can be used to provide ADOT Facility, Equipment/Material Storage Facility, and Rest Area monitoring. OmniWatch® uses the same communication features as WeatherScene® and will be compatible with the Communications Plan if it is used.

6.0 RESULTS AND CONCLUSIONS

Through this research project, ADOT will create and implement a reliable communications design for the statewide RWIS infrastructure. When completed, this new communications architecture will be both robust and very flexible. It not only will permit full connectivity with the RWIS sites, but also with the Truck Escape Ramp detectors and with other future ITS infrastructure. This flexibility is the result of using “Open” standards to permit easy integration of the system. This Communications Plan lays out a practical solution wherein the majority of remote site connections will be via direct phone connection, cell phone, or via indirect phone connections using RF spread spectrum links.

This Communication Architecture meets all of the ADOT requirements and establishes excellent real time connectivity all the way from the remote RWIS site to a web page where the data and traffic pictures can be viewed. ADOT has a difficult communications environment because of:

- Large geographic areas without easy land based telephone service,
- Large areas that are U.S. Government or Indian Tribal Government owned,
- Mountain and desert terrains that limit wireless communication options, and
- Difficult weather conditions consisting of high winds, cold and snow, thunderstorms, blowing dust, and very high temperatures.

The new ADOT Communications Architecture accommodates all of these difficulties and provides ADOT with current information from remote sites. NTCIP standards, newer commercially available communication equipment, and Internet-based publication methods will be used to successfully meet these challenges. Also, a single contractor has been chosen to upgrade existing RWIS sites and install new RWIS sites, thus ensuring a consistent implementation approach and equipment interoperability.

ADOT believes that adherence to NTCIP and “Open” standards is very important in being able to adapt the RWIS Communications Plan to changes in technology and in performance over a long period of time. Through this research project, ADOT has allowed for future upgrades in technology by creating this plan, and by implementing these standards.

7.0 REFERENCES

1. NTCIP 9001, Version 2.06, *The NTCIP Guide*, National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801, December 2000.

2. NTCIP 2103, Version 1.13, *National Transportation Communications for ITS Protocol (NTCIP) Point-to-Point Protocol over RS-232 Subnetwork Profile (Recommended/Draft),* National Electrical Manufacturers Association (NEMA), February 2002.

3. NTCIP 2202:2001, Version 1.05, *National Transportation Communications for ITS Protocol (NTCIP) Internet (TCP/IP and UDP/IP) Transport Protocol,* National Electrical Manufacturers Association (NEMA), December 2001.

4. NTCIP 2301:2001, Version 1.08, *National Transportation Communications for ITS Protocol (NTCIP) Simple Transportation Management Framework Application Profile,* National Electrical Manufacturers Association (NEMA), December 2001.

5. NTCIP 1204:1998, Version 1.13 (including Amendment 1), *National Transportation Communications for ITS Protocol (NTCIP) Object Definitions for Environmental Sensor Stations (ESS),* National Electrical Manufacturers Association (NEMA), November 23, 2001.

6. NTCIP 1201, TS 3.4 – 1998, *National Transportation Communications for ITS Protocol (NTCIP) Global Object Definitions,* National Electrical Manufacturers Association (NEMA), 1998.

7. NTCIP 1209, Version 1.13, *National Transportation Communications for ITS Protocol (NTCIP) Object Definitions for Transportation Sensor Systems (Recommended/Draft),* National Electrical Manufacturers Association (NEMA), February 2002.

8. *WeatherScene® Remote Processor Unit NTCIP Compliance Document*, System Innovations, Inc., 1551 Forbes Street, Fredericksburg, VA, 22405, 15 May 2002.

Reference 8, WeatherScene® Remote Processor Unit NTCIP Compliance Document,* is included as Appendix A. References 1 through 7 are publicly available NTCIP Standards documents and are not included in this document.

APPENDIX

WeatherScene®
Remote Processor Unit
NTCIP Compliance Document

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The Leader in High Technology Solutions
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WEATHERSCENE®
REMOTE PROCESSOR UNIT
NTCIP Compliance Document

Version: Original
Issued: 15 May 2002

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REVISION HISTORY

Version	Primary Author(s)	Description of Version	Date Completed
Draft	Richard Porter	Initial draft created for distribution and review comments	05/15/02
Preliminary		Second draft incorporating initial review comments, distributed for final review	
Final		First complete draft, which is placed under change control	
Revision 1		Revised draft, revised according to the change control process and maintained under change control	

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FIGURES

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1. INTRODUCTION

WeatherScene® is a remote highway monitoring system, designed to provide critical highway information to departments of transportation using wireless, battery-powered systems. Each WeatherScene® system is highly configurable and may provide imagery, weather, road condition, and traffic data, in any combination. The primary roadside equipment in the WeatherScene® system is the Remote Processor Unit (RPU). The RPU integrates data from various sensors, including weather, road condition and traffic sensors, to provide detailed information on travel conditions. The interface to the RPU is compliant with the National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP).

The purpose of the RPU NTCIP compliance document is to describe, in detail, the design and implementation of NTCIP-compliant communications in the WeatherScene® Remote Processor Unit (RPU).

1.1 Objectives

The objective of the designing and documenting NTCIP-compliant communications in the WeatherScene® RPU is to promote interoperability between WeatherScene® roadside equipment and non-WeatherScene® servers and controllers.

1.2 Scope

This compliance document describes the plant, subnetwork, transport, application, and information layers of the NTCIP-compliant protocol stack implemented within the WeatherScene® RPU. Particular attention (and detail) is provided for the application layer, describing the supported NTCIP and vendor-specific objects. This document assumes a working knowledge of the NTCIP family of communications specifications. For additional detail, see the cited references.

1.3 Reference Material

[1] NTCIP 9001, Version 2.06, *The NTCIP Guide*, National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801, December 2000.

[2] NTCIP 2103, Version 1.13, *National Transportation Communications for ITS Protocol (NTCIP) Point-to-Point Protocol over RS-232 Subnetwork Profile (Recommended/Draft),* National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801, February 2002.

[3] NTCIP 2202:2001, Version 1.05, *National Transportation Communications for ITS Protocol (NTCIP) Internet (TCP/IP and UDP/IP) Transport Protocol,* National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801, December 2001.

[4] NTCIP 2301:2001, Version 1.08, *National Transportation Communications for ITS Protocol (NTCIP) Simple Transportation Management Framework Application Profile,* National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801, December 2001.

[5] NTCIP 1204:1998, Version 1.13 (including Amendment 1), *National Transportation Communications for ITS Protocol (NTCIP) Object Definitions for Environmental Sensor Stations (ESS),* National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801, November 23, 2001.

[6] NTCIP 1201, TS 3.4 – 1998, *National Transportation Communications for ITS Protocol (NTCIP) Global Object Definitions,* National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801.

[7] NTCIP 1209, Version 1.13, *National Transportation Communications for ITS Protocol (NTCIP) Object Definitions for Transportation Sensor Systems (Recommended/Draft),* National Electrical Manufacturers Association (NEMA), 1300 N. 17th Street, Suite 1847, Rosslyn, Virginia 22209-3801, February 2002.

1.4 Definitions And Acronyms

DUN	Dial Up Networking
ESS	Environmental Sensor Station
IEEE	Institute of Electrical and Electronics Engineers
IANA	Internet Assigned Numbers Authority
IP	Internet Protocol
ITS	Intelligent Transportation Systems
MIB	Management Information Base
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communication for ITS Protocol
PICS	Protocol Implementation Conformance Statement
PRL	Profile Requirements List
PPP	Point-to-Point Protocol
RFC	Request for Comment
RPU	Remote Processor Unit
RWIS	Road Weather Information System
SII	System Innovations, Inc.
SNMP	Simple Network Management Protocol
STMF	Simple Transportation Management Framework
TCP	Transmission Control Protocol
TSS	Transportation Sensor Station
UDP	User Datagram Protocol

2. NTCIP COMPLIANCE

NTCIP compliance of the WeatherScene® RPU is summarized by the diagram in Figure 1, excerpted from Reference 1. In addition, Table 1 outlines the detailed descriptions of the WeatherScene® RPU's NTCIP compliance.

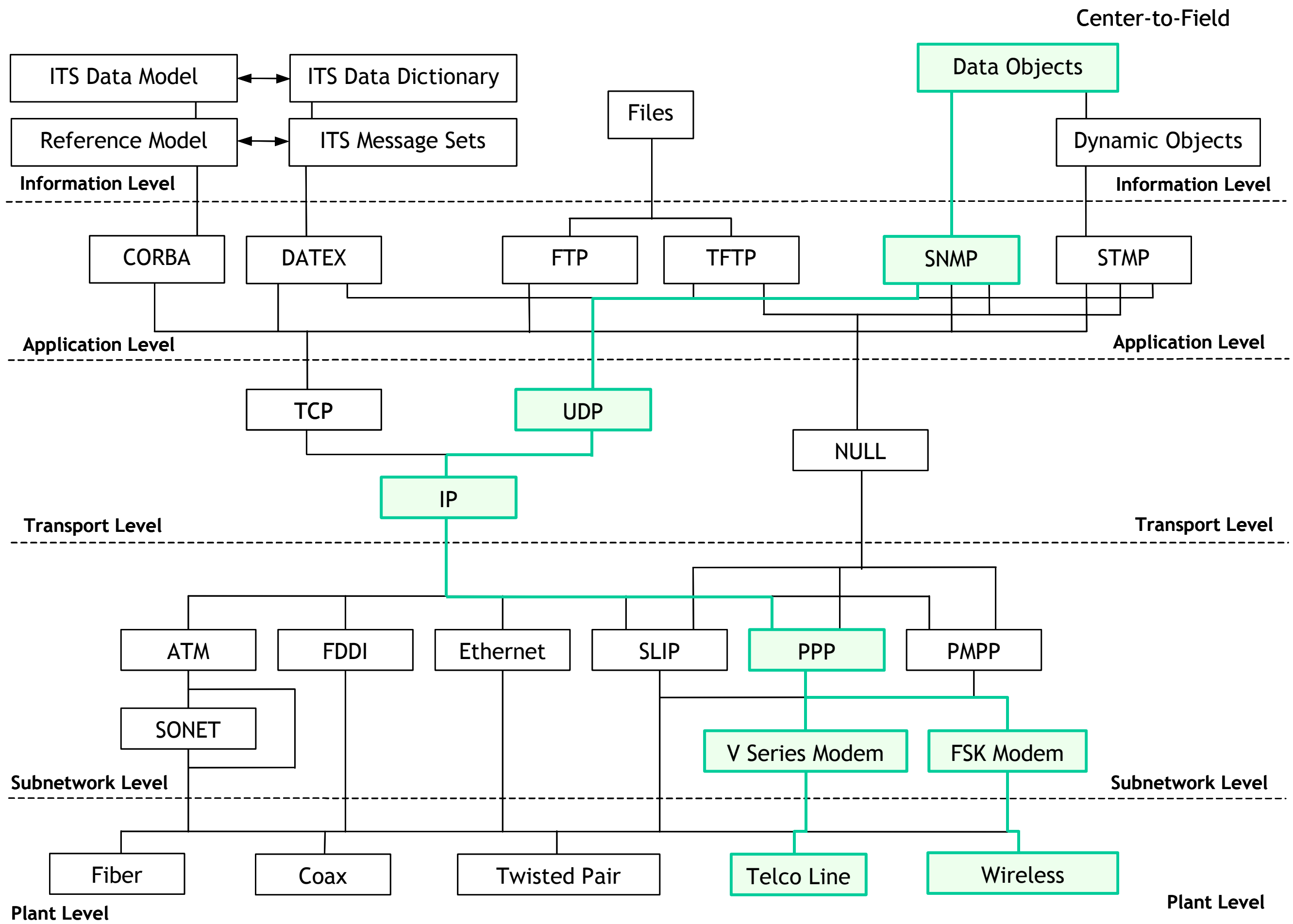

Figure 1. WeatherScene® NTCIP Compliance Summary Diagram

Table 1. NTCIP Compliance Description Index

Level	Top-Level NTCIP Compliance Description	Section
Plant	The WeatherScene® RPU uses standard telephone lines or wireless links as its plant or physical layer.	2.1
Subnetwork	The WeatherScene® RPU uses Point-to-Point Protocol (PPP) over V-series telephone modems or wireless data modems as its subnetwork level	2.2
Transport	The WeatherScene® RPU uses User Datagram Protocol (UDP) over Internet Protocol (IP) as its transport level.	2.3
Application	The WeatherScene® RPU uses Simple Network Management Protocol (SNMP) as its application level.	2.4
Information	The WeatherScene® RPU uses data objects from the following Management Information Bases • Environmental Sensor Station Objects • WeatherScene®-specific Objects	2.5

2.1 Plant Profile

The plant level interface to the WeatherScene® RPU is standard telco line or wireless, as appropriate for the given WeatherScene® installation. There are no special NTCIP requirements specified for the plant level.

2.2 Subnetwork Profile

The subnetwork profile specifies a set of protocols and standards applicable to the data link and physical layers of the OSI reference model. The subnetwork profile for the WeatherScene® RPU is the point-to-point protocol (PPP) over RS232. NTCIP 2103 (Reference 2), which is currently in draft, documents the detailed requirements for this subnetwork protocol. The WeatherScene® RPU is fully compliant with NTCIP 2103 (draft), as documented in the completed profile requirements list (PRL) and protocol implementation conformance statement (PICS) contained in Appendix A, as required by NTCIP 2103. Upon balloting and approval of this standard, the WeatherScene® RPU interface will be reviewed to determine its compliance with the approved standard.

2.3 Transport Profile

The transport level profile specifies a set of protocols and standards applicable to the transport and network layers of the OSI reference model. The transport profile provides message transport and delivery services between transportation devices and management stations. The transport profile for the WeatherScene® RPU is the Internet transport profile, specifically user datagram protocol (UDP) over Internet protocol (IP). NTCIP 2202 (Reference 3), documents the detailed requirements for this transport protocol. The WeatherScene® RPU is fully compliant with NTCIP 2202, as documented in the completed PRL and PICS contained in Appendix B, as required by NTCIP 2202.

2.4 Application Profile

The application level profile specifies a set of protocols and standards applicable to the application, presentation, and session layers of the OSI reference model. The application profile should provide message authentication, information management, and data representation services for devices and management stations. The application profile for the WeatherScene® RPU is the simple transportation management framework (STMF) application profile, conformance level 1. NTCIP 2301 (Reference 4) documents the detailed requirements for this application profile. The WeatherScene® RPU is fully compliant with NTCIP 2301, as documented in the completed PRL and PICS contained in Appendix C, as required by NTCIP 2301.

2.5 Information Profile

The information profile specifies logically grouped sets of data that devices and management stations can exchange. These object definitions, documented in standard management information bases (MIBs), provide a common basis for peers to communicate transportation-related information. The WeatherScene® RPU is an environmental sensor station and, thus, complies with the following NTCIP object definitions:

- NTCIP object definitions for ESS, documented in NTCIP 1204 (Reference 5)
- WeatherScene®-specific object definitions

The following sections detail the information profile compliance of the WeatherScene® RPU, as well as, document WeatherScene®-specific objects.

2.5.1 Environmental Sensor Station Objects

NTCIP 1204 specifies conformance groups to be used as minimum requirements for specifying varying degrees of compliance with the standard. Table 2 summarizes the WeatherScene® RPU's conformance with the groups documented in NTCIP 1204. Each supported group will be detailed in a subsequent section indicated in the last column of Table 2.

Table 2. ESS MIB Conformance Group Summary

Conformance Group	Conformance Requirement	WeatherScene® Conformance	Details in Section…
Configuration	mandatory	Yes	2.5.1.1
Database Management	optional	No	N/A
Time Management	mandatory	Yes	2.5.1.2
Timebase Event Schedule	optional	No	N/A
Report	optional	No	N/A
STMF	optional	No	N/A
PMPP	optional	No	N/A
ESS Configuration	mandatory	Yes	2.5.1.3
ESS Location	mandatory	Yes	2.5.1.4
Pressure	optional	Yes	2.5.1.5
Wind Data	optional	Yes	2.5.1.6
Mobile Wind Data	optional	No	N/A
Basic Temperature Data	optional	Yes	2.5.1.7
Enhanced Temperature Data	optional	Yes	2.5.1.8
Basic Precipitation Data	optional	Yes	2.5.1.9
Standard Precipitation Data	optional	Yes	2.5.1.10
Enhanced Precipitation Data	optional	Yes	2.5.1.11
Emerging Precipitation Data	optional	No	N/A
Solar Radiation	optional	Yes	2.5.1.12
Visibility Data	optional	Yes	2.5.1.13
Standard Pavement Sensor Data	optional	Yes	2.5.1.14
Enhanced Pavement Sensor Data	optional	Yes	2.5.1.15
Standard Sub-Surface Sensor Data	optional	Yes	2.5.1.16
Enhanced Sub-Surface Sensor Data	optional	No	N/A
Emerging Mobile Platform	optional	No	N/A
Pavement Treatment	optional	No	N/A
Air Quality	optional	No	N/A
Staffed Station	optional	No	N/A

2.5.1.1 Configuration Conformance Group

The Global Configuration Conformance Group consists of global objects related to general configuration information, as detailed in Table 3.

Table 3. Configuration Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
globalSetIDParameter	TS 3.4 [Ref 6]	Yes
globalMaxModules	TS 3.4 [Ref 6]	Yes
globalModuleTable	TS 3.4 [Ref 6]	Yes
moduleNumber	TS 3.4 [Ref 6]	Yes
moduleDeviceNode	TS 3.4 [Ref 6]	Yes
moduleMake	TS 3.4 [Ref 6]	Yes
moduleModel	TS 3.4 [Ref 6]	Yes
moduleVersion	TS 3.4 [Ref 6]	Yes
moduleType	TS 3.4 [Ref 6]	Yes

2.5.1.2 Time Management Conformance Group

The Global Time Management Conformance Group consists of global objects related to time management functions. The Time Database Management Conformance Group shall consist of the following objects:

Table 4. Time Management Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
globalTime	TS 3.4 [Ref 6]	Yes
globalDaylightSaving	TS 3.4 [Ref 6]	Yes

2.5.1.3 ESS Configuration Conformance Group

The ESS Configuration Conformance Group consists of a variety of ESS objects related to general configuration information. The ESS Conformance Group shall consist of the following objects and tables:

Table 5. ESS Configuration Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essNtcipCategory	NTCIP 1204	Yes
essNtcipSiteDescription	NTCIP 1204	Yes
essTypeofStation	NTCIP 1204	Yes

2.5.1.4 ESS Location Conformance Group

The ESS Location Conformance Group consists of objects that specify the location of the ESS. The ESS Location Conformance Group shall consist of the following objects:

Table 6. ESS Location Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essLatitude	NTCIP 1204	Yes
essLongitude	NTCIP 1204	Yes
essReferenceHeight	NTCIP 1204	Yes

2.5.1.5 Pressure Conformance Group

The Pressure Conformance Group consists of objects that specify the pressure sensor height and pressure measurement of the ESS. The Pressure Conformance Group shall consist of the following objects:

Table 7. Pressure Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essPressureHeight	NTCIP 1204	Yes
essAtmosphericPressure	NTCIP 1204	Yes

2.5.1.6 Wind Data Conformance Group

The Wind Data Conformance Group consists of objects that describe the wind sensor elevation and wind data collected by the ESS. The Wind Data Conformance Group shall consist of the following objects:

Table 8. Wind Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essWindSensorHeight	NTCIP 1204	Yes
essAvgWindDirection	NTCIP 1204	Yes
essAvgWindSpeed	NTCIP 1204	Yes
essMaxWindGustSpeed	NTCIP 1204	Yes
essMaxWindGustDir	NTCIP 1204	Yes

2.5.1.7 Basic Temperature Data Conformance Group

The Basic Temperature Data Conformance Group consists of objects that describe the basic temperature data collected by the ESS. The Basic Temperature Data Conformance Group shall consist of the following objects:

Table 9. Basic Temperature Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essNumTemperatureSensors	NTCIP 1204	Yes
Temperature Sensor Table	NTCIP 1204	Yes
essTemperatureSensorIndex	NTCIP 1204	Yes
essTemperatureSensorHeight	NTCIP 1204	Yes
essAirTemperature	NTCIP 1204	Yes
essMaxTemp	NTCIP 1204	Yes
essMinTemp	NTCIP 1204	Yes

2.5.1.8 Enhanced Temperature Data Conformance Group

The Enhanced Temperature Data Conformance Group consists of objects that describe the enhanced temperature data collected by the ESS. The Enhanced Temperature Data Conformance Group shall consist of the following objects:

Table 10. Enhanced Temperature Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essNumTemperatureSensors	NTCIP 1204	Yes
Temperature Sensor Table	NTCIP 1204	Yes
essTemperatureSensorIndex	NTCIP 1204	Yes
essTemperatureSensorHeight	NTCIP 1204	Yes
essAirTemperature	NTCIP 1204	Yes
essMaxTemp	NTCIP 1204	Yes
essMinTemp	NTCIP 1204	Yes
essRelativeHumidity	NTCIP 1204	Yes
essWetBulbTemp	NTCIP 1204	Yes
essDewpointTemp	NTCIP 1204	Yes

2.5.1.9 Basic Precipitation Data Conformance Group

The Basic Precipitation Data Conformance Group consists of objects that describe the precipitation data collected by the ESS. The Basic Precipitation Data Conformance Group shall consist of the following objects:

Table 11. Basic Precipitation Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essPrecipYesNo	NTCIP 1204	Yes

2.5.1.10 Standard Precipitation Data Conformance Group

The Standard Precipitation Data Conformance Group consists of objects that describe the precipitation data collected by the ESS. The Standard Precipitation Data Conformance Group shall consist of the following objects:

Table 12. Standard Precipitation Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essPrecipRate	NTCIP 1204	Yes
essPrecipitationStartTime	NTCIP 1204	Yes
essPrecipitationEndTime	NTCIP 1204	Yes

2.5.1.11 Enhanced Precipitation Data Conformance Group

The Enhanced Precipitation Data Conformance Group consists of objects that describe the precipitation data collected by the ESS. The Enhanced Precipitation Data Conformance Group shall consist of the following objects:

Table 13. Enhanced Precipitation Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essPrecipRate	NTCIP 1204	Yes
essPrecipitationStartTime	NTCIP 1204	Yes
essPrecipitationEndTime	NTCIP 1204	Yes
essPrecipitationOneHour	NTCIP 1204	Yes
essPrecipitationThreeHour	NTCIP 1204	Yes
essPrecipitationSixHour	NTCIP 1204	Yes
essPrecipitationTwelveHour	NTCIP 1204	Yes
essPrecipitation24Hours	NTCIP 1204	Yes
essPrecipSituation	NTCIP 1204	Yes

2.5.1.12 Solar Radiation Conformance Group

The Solar Radiation Conformance Group consists of objects that describe the solar radiation data collected by the ESS. The Solar Radiation Conformance Group shall consist of the following objects:

Table 14. Solar Radiation Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essSolarRadiation	NTCIP 1204	Yes
essTotalSun	NTCIP 1204	Yes

2.5.1.13 Visibility Data Conformance Group

The Visibility Data Conformance Group consists of objects that describe the wind data collected by the ESS. The Visibility Data Conformance Group shall consist of the following objects:

Table 15. Visibility Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
essVisibility	NTCIP 1204	Yes
essVisibilitySituation	NTCIP 1204	Yes

2.5.1.14 Standard Pavement Sensor Data Conformance Group

The Standard Pavement Sensor Data Conformance Group consists of objects that describe the standard pavement surface data collected by the ESS. The Standard Pavement Sensor Data Conformance Group shall consist of the following objects:

Table 16. Standard Pavement Sensor Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
numEssPavementSensors	NTCIP 1204	Yes
essPavementSensorTable	NTCIP 1204	Yes
essPavementSensorIndex	NTCIP 1204	Yes
essPavementSensorLocation	NTCIP 1204	Yes
essPavementType	NTCIP 1204	Yes
essPavementElevation	NTCIP 1204	Yes
essPavementExposure	NTCIP 1204	Yes
essPavementSensorType	NTCIP 1204	Yes
essSurfaceStatus	NTCIP 1204	Yes
essSurfaceTemperature	NTCIP 1204	Yes
essPavementSensorError	NTCIP 1204	Yes

2.5.1.15 Enhanced Pavement Sensor Data Conformance Group

The Enhanced Pavement Sensor Data Conformance Group consists of objects that describe the standard and enhanced pavement surface data collected by the ESS. A device that claims conformance to the Enhanced Pavement Sensor Data Conformance Group shall support all of the following objects:

Table 17. Enhanced Pavement Sensor Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
numEssPavementSensors	NTCIP 1204	Yes
essPavementSensorTable	NTCIP 1204	Yes
essPavementSensorIndex	NTCIP 1204	Yes
essPavementSensorLocation	NTCIP 1204	Yes
essPavementType	NTCIP 1204	Yes
essPavementElevation	NTCIP 1204	Yes
essPavementExposure	NTCIP 1204	Yes
essPavementSensorType	NTCIP 1204	Yes
essSurfaceStatus	NTCIP 1204	Yes
essSurfaceTemperature	NTCIP 1204	Yes
essPavementSensorError	NTCIP 1204	Yes
essPavementTemperature	NTCIP 1204	Yes
essSurfaceWaterDepth	NTCIP 1204	Yes
essSurfaceFreezePoint	NTCIP 1204	Yes
essSurfaceBlackIceSignal	NTCIP 1204	Yes

2.5.1.16 Standard Subsurface Sensor Data Conformance Group

The Subsurface Sensor Data Conformance Group consists of objects that describe the pavement surface data collected by the ESS. The Subsurface Sensor Data Conformance Group shall consist of the following objects:

Table 18. Standard Subsurface Sensor Data Conformance Group

Object Table or Name	Reference	WeatherScene® Conformance
numEssSubSurfaceSensors	NTCIP 1204	Yes
essSubSurfaceSensorTable	NTCIP 1204	Yes
essSubSurfaceSensorIndex	NTCIP 1204	Yes
essSubSurfaceSensorLocation	NTCIP 1204	Yes
essSubSurfaceType	NTCIP 1204	Yes
essSubSurfaceSensorDepth	NTCIP 1204	Yes
essSubSurfaceTemperature	NTCIP 1204	Yes
essSubSurfaceSensorError	NTCIP 1204	Yes

2.5.2 WeatherScene-Specific Objects

As shown in Figure 2, the WeatherScene®-specific objects reside in two nodes under the SII private enterprise node (10413), which was granted by the Internet Assigned Numbers Authority (IANA). The two nodes are named TSS (4) and RPU (1). These will be detailed in the following sections to promote interoperability between management stations and WeatherScene® roadside equipment.

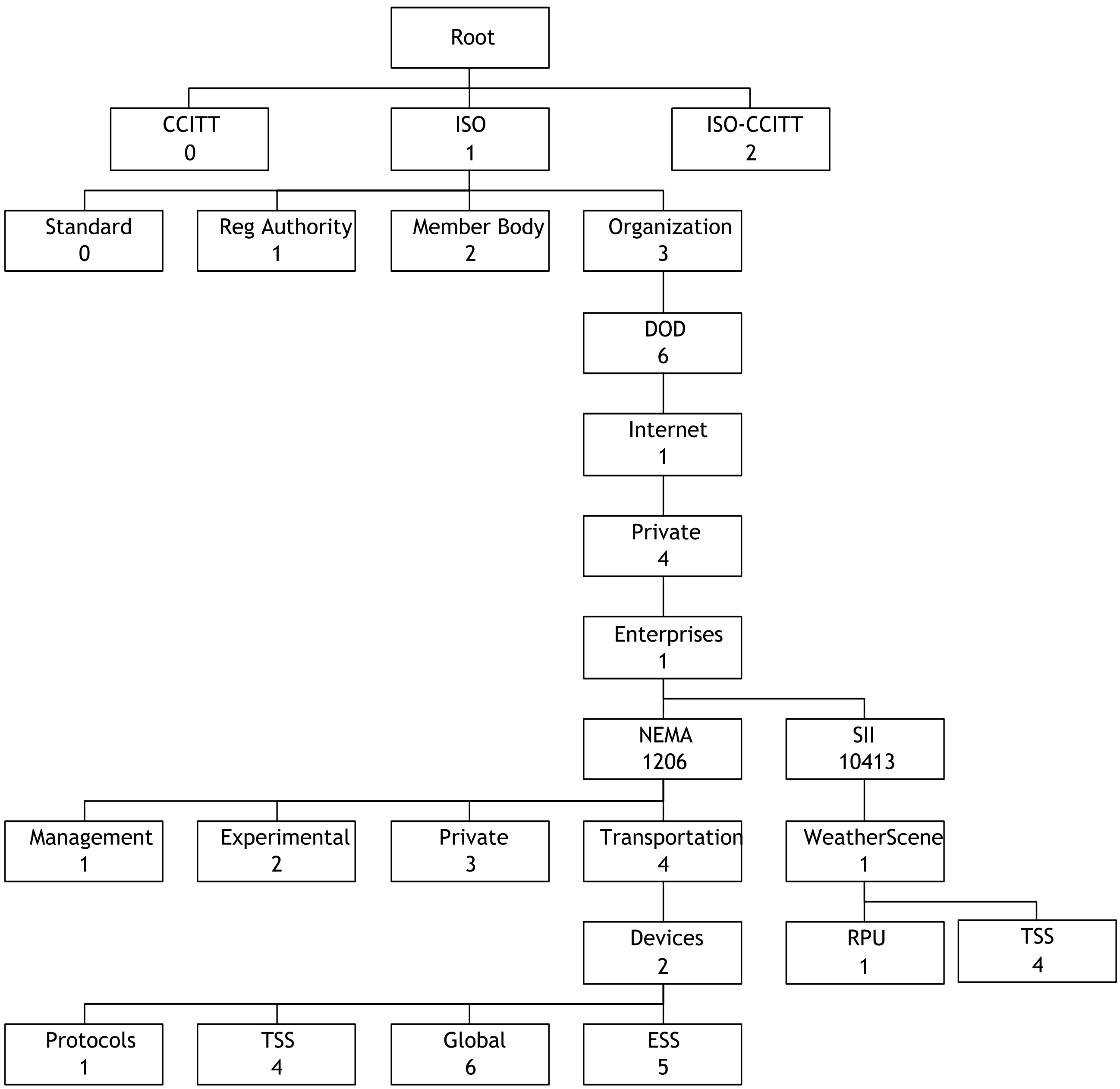

Figure 2. WeatherScene® MIB Node Location Diagram

2.5.2.1 WeatherScene® TSS-Like Objects

WeatherScene® RPUs include optional traffic sensor systems to provide information, such as traffic counts, lane occupancies, and vehicle speeds. The model for the object definitions in this WeatherScene®-specific node is NTCIP 1209 (Reference 7), which is currently in draft form. Upon balloting and approval of this standard, the WeatherScene® RPU object definitions will be reviewed to determine its compliance with the approved standard. Table 19 and subsequent sections provide an overview of the objects in this MIB. For more detail, see the MIB in Appendix D.

Table 19. WeatherScene® TSS-Like Object Summary

Group	Summary Description
Configuration	This group provides objects related to the configuration of the traffic sensor zones.
TSS Data Collection	This group provides objects related to the collection and storage of the traffic sensor data.

2.5.2.1.1 TSS System Setup Group

The TSS System Setup Group consists of a variety of TSS objects related to general configuration and capability information. A summary of the objects in this group is contained in Table 20.

Table 20. System Setup Conformance Group Objects

Object Table or Name	Summary Description
sensorSystemStatus	Indicates the general status of the sensor system.
sensorSystemDataType	Indicates the type of data extracted from the sensor.
maxSensorZones	Indicates the number of active zones.
sensorZoneTable	Contains configuration data for the zones.
sensorZoneNumber	Indicates the zone number.
sensorZoneOptions	Indicates the options configured for this zone.
sensorZoneSamplePeriod	Indicates the sample period for this zone.
sensorZoneLabel	Indicates the text label (description) for this zone.
clockAvailable	Indicates whether a clock is available for timekeeping.
vehicleClassification	Configures whether vehicle classification is possible.

2.5.2.1.2 TSS Data Collection Group

The TSS Data Collection Group consists of a variety of TSS objects related to the accumulation of statistical information about vehicles. A summary of the objects in this group is contained in Table 21.

Table 21. Data Collection Conformance Group Objects

Object Table or Name	Summary Description
dataCollectionTable	Contains the most recent zone data.
collectionIndex	Index of the collection (also the zone number).

Object Table or Name	Summary Description
endTime	Time of the collection.
zoneStatus	Status of the zone at the time of the collection.
percentOccupancy	Occupancy of the zone over the interval of the collection.
speedData	Vehicle speed in the zone over the interval of the collection.
volumeData	Vehicle count in the zone over the interval of the collection.
volumeCommercial	Commercial truck count in the zone over the interval.
volumeTracTrail	Tractor trailer count in the zone over the interval.
dataBufferTable	Contains historical zone data.
bufferIndex	Index of the collection (also the zone number).
endTimeBuffer	Time of the collection.
zoneStatusBuffer	Status of the zone at the time of the collection.
percentOccupancyBuffer	Occupancy of the zone over the interval of the collection.
speedDataBuffer	Vehicle speed in the zone over the interval of the collection.
volumeDataBuffer	Vehicle count in the zone over the interval of the collection.
volumeCommercialBuffer	Commercial truck count in the zone over the interval.
volumeTracTrailBuffer	Tractor trailer count in the zone over the interval.

2.5.2.2 WeatherScene® Objects

WeatherScene® RPUs include a vendor-specific MIB to provide access to the configuration, status and control information not available through the NTCIP standard MIBs. The following sections provide an overview of the objects in this MIB. For more detail, see the MIB in Appendix E.

Table 22. WeatherScene® MIB Group Summary

Group	Summary Description
RPU Setup	This group provides objects related to the configuration of the WeatherScene® RPU.
RPU Status	This group provides objects related to the status of the WeatherScene® RPU.
RPU Video	This group provides objects related to the control and collection of video from the WeatherScene® RPU.
RPU Net Configuration	This group provides objects related to the configuration of the networking layers within the WeatherScene® RPU.
RPU Control	This group provides objects related to the control of gadgets within the WeatherScene® RPU.
RPU Alarms	This group provides objects related to the configuration of alarm processing within the WeatherScene® RPU.
RPU Schedules	This group provides objects related to the configuration of the measurement scheduler within the WeatherScene® RPU.
RPU Data Logs	This group provides objects related to the logging of sensor data within the WeatherScene® RPU.

2.5.2.2.1 RPU Setup Group

The RPU Setup Group contains the configuration objects for the WeatherScene remote processor unit (RPU). The RPU Setup Group consists of the following objects:

Table 23. RPU Setup Group Objects

Object Table or Name	Summary Description
ESS Objects with improved access	This is a collection of ESS objects (explained in the ESS MIB) with read-only access in the ESS MIB. These objects require configuration at the factory or roadside, so they are duplicated in the WeatherScene® MIB with read-write access to provide the configuration capability.
rpuSensorMask	Indicates which sensors are connected to the RPU.
rpuPowerMask	Indicates which sensors should be powered continuously.

2.5.2.2.2 RPU Status Group

The RPU Status Group contains the objects related to Built In Test (BIT) for the WeatherScene remote processor unit (RPU). The RPU Status Group consists of the following objects:

Table 24. RPU Status Group Objects

Object Table or Name	Summary Description
rpuStatus	Indicates the current status of the RPU and sensors.
rpuLastError	Indicates the last error logged by the RPU.
rpuMemoryStatus	Indicates the status of the RPU memory.
rpuPeripheralStatus	Indicates the status of the RPU peripherals.
rpuBatteryVoltage	Indicates the main battery voltage.
rpuChargingVoltage	Indicates the charging voltage for solar powered systems.
rpuReferenceVoltageNegative	Indicates the level of the A/D negative reference.
rpuReferenceVoltagePositive	Indicates the level of the A/D positive reference.
rpuWeatherSensorStatus	Indicates the state of the weather sensor task.
rpuRoadSensorStatus	Indicates the state of the road sensor task.
rpuTrafficSensorStatus	Indicates the state of the traffic sensor task.
rpuWindSensorStatus	Indicates the state of the wind sensor task.
rpuAnalogSensorStatus	Indicates the state of the analog sensor task.

2.5.2.2.3 RPU Video Group

The RPU Video Group contains the objects related to video in the WeatherScene® remote processor unit (RPU). The RPU Video Group consists of the following objects:

Table 25. RPU Video Group Objects

Object Table or Name	Summary Description
rpuNumImages	Indicates the number of images stored by the RPU.
rpuImageTable	Contains information about stored images.
rpuImageIndex	Indicates the index of this image.
rpuImageLength	Indicates the size of this image.
rpuImageCamera	Indicates the camera number for this image.
rpuImageTime	Indicates the time this image was taken.
rpuImage	Image data.
rpuVideoControl	Provides control of the image collection process.

2.5.2.2.4 RPU Network Configuration Group

The RPU Network Configuration Group contains the objects related to the capability of the WeatherScene® remote processor unit (RPU) to initiate a call back to the central server. The RPU Network Configuration Group consists of the following objects:

Table 26. RPU Network Configuration Group Objects

Object Table or Name	Summary Description
rpuPrimaryPhone	Indicates the first phone number that the RPU should dial in case of a reportable event.
rpuSecondaryPhone	Indicates the phone number that the RPU should dial in case of a reportable event and a failure on the primary phone.
rpuPPPKeyword	Indicates the keyword to be used to begin PPP negotiations.
rpuTrapHost	Indicates the host (i.e., IP address) to which alarms will be sent.
rpuPortNumber	Indicates the port number to which imagery should be transferred.

2.5.2.2.5 RPU Control Group

The RPU Control Group contains the control objects for the WeatherScene® remote processor unit (RPU). The RPU Control Group consists of the following objects:

Table 27. RPU Control Group Objects

Object Table or Name	Summary Description
RpuReset	Allows a remote reset of the RPU.
RpuRelay1Control	Provides control of an electromechanical relay in the RPU.
RpuRelay2Control	Provides control of an electromechanical relay in the RPU.
rpuDigitalInputs	Indicates the status of 8 digital inputs to the RPU.

2.5.2.2.6 RPU Alarms Group

The RPU Alarms Group contains the objects related to alarms for the WeatherScene® remote processor unit (RPU). The RPU Alarms Group consists of the following objects:

Table 28. RPU Alarms Group Objects

Object Table or Name	Summary Description
rpuMaxAlarms	Maximum number of alarms in the alarm table.
rpuAlarmThresholds	Table of alarm thresholds.
thresholdIndex	Index of this alarm.
thresholdParameter	Indicates the measurement parameter to check.
thresholdValue	Indicates the threshold that must be crossed.
thresholdType	Indicates the type of threshold.
rpuDigitalAlarms	Provides control over digital input alarms.

2.5.2.2.7 RPU Schedule Group

The RPU Schedule Group contains the scheduling objects for the WeatherScene® remote processor unit (RPU). The RPU Schedule Group consists of the following objects:

Table 29. RPU Schedule Group Objects

Object Table or Name	Summary Description
rpuMaxSchedules	Maximum number of schedules in the alarm table.
rpuScheduleEntries	Table of schedule entries.
scheduleIndex	Index of this schedule.
scheduleParameter	Indicates the parameter to be scheduled.
scheduleValue	Indicates the value of the schedule interval.
scheduleType	Indicates the type of schedule.

2.5.2.2.8 RPU Logs Group

The RPU Logs Group contains the objects related to data logging for the WeatherScene® remote processor unit (RPU). The RPU Logs Group consists of the following objects:

Table 30. RPU Logs Group Objects

Object Table or Name	Summary Description
logMaxWeather	Maximum number of entries in the weather table.
logWeatherEntries	Table of weather entries.
logWeatherIndex	Index of this entry.
logWeatherTime	Indicates the time of the measurement.
logWeatherTemperature	Indicates the air temperature at the measurement time.
logWeatherPressure	Indicates the pressure at the measurement time.
logWeatherHumidity	Indicates the humidity at the measurement time.
logWeatherWindAve	Indicates the wind speed at the measurement time.
logWeatherWindGust	Indicates the wind gust at the measurement time.
logWeatherWindDir	Indicates the wind direction at the measurement time.
logWeatherVisibility	Indicates the visibility at the measurement time.
logMaxPavementSensors	Maximum number of entries in the surface table.
logPavementSensorTable	Table of surface entries.
logPavementSensorIndex	Indicates the index of the surface sensor.
logPavementSensorTime	Indicates the measurement time.
logPavementSensorNumber	Indicates the sensor that generated this data.
logSurfaceStatus	Indicates the sensor status at the measurement time.
logSurfaceTemperature	Indicates the temperature at the measurement time.
logSurfaceSalinity	Indicates the salinity at the measurement time.
logSurfaceFreezePoint	Indicates the freezing point at the measurement time.
logSubSurfaceSensors	Maximum number of entries in the subsurface table.
logSubSurfaceSensorTable	Table of subsurface entries.
logSubSurfaceSensorIndex	Indicates the index of the subsurface sensor.
logSubSurfaceSensorTime	Indicates the measurement time.
logSubSurfaceSensorNumber	Indicates the sensor that generated this data.
logSubsurfaceTemperature	Indicates the air temperature at the measurement time.